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Fuzzy Inference System Based Robust Digital Image Watermarking Technique using Discrete Cosine Transform

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Abstract

Digital Watermarking has evolved as one of the latest technologies for digital media copyright protection. Watermarking of images can be done in many ways and one of the proposed algorithms for image watermarking is by utilizing Fuzzy Logic. It is similar to the concept of a Fuzzy set, each element can be defined by an ordered pair, in which one is the value and other is the membership function value. Fuzzy logic systems can explain inaccurate information and explain their decisions. Fuzzy inference system is the simplest way of performing Fuzzy Logic. In the proposed method, three Fuzzy inference models are used to generate the weighing factor for embedding the watermark and input to the Fuzzy Inference System is taken from the Human Visual System model. The Performance measures used in the Process are Peak Signal to Noise Ratio, Normalized Cross Correlation. The Proposed algorithm is immune to various Image Processing attacks.

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Keywords: Digital Image Watermarking; Discrete Cosine Transform; Human Visual System; Fuzzy Inference System; Normalized Cross Correlation; Peak Signal to Noise Ratio.

1. Introduction

Watermarking attempts to hide a message allied to the authentic content of the digital signal. Watermarking is one of the best proposed solutions for copyright protection of digital images[1]. The procedure of inserting a watermark i.e. in an audio/visual object is defined as watermarking. In watermarking, the watermark is added to the cover data in such a way that it remains in it. It is an idea strictly related to steganography, in a way they both hide

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message inside a multimedia signal. However, what parts them is their goal[2,3]. Watermarking hides message associated with the authentic content of the digital signal, whereas in steganography the multimedia signal has no relation to the message, and it is only used as an asylum to hide its presence, watermarking mainly concentrates on the robustness of the data hidden inside the cover. Embedding of the watermark into a host image can be done in three ways, first by placing the watermark signal into the original image directly; as we are embedding the watermark into the pixels directly, this method is called as spatial domain method[4]. Second, we can convert the host image values into its transform domain components and embed the watermark into the components; this method is called as transform domain method[5], third type of method make use of both the approaches for embedding watermark and is called as hybrid domain method[6]. Each method has its own merits and demerits based on the application and embedding method chosen.

The watermark can be embedded through visible and invisible means such that it can be given as the proof of lawful ownership. Several attacks may be experienced because the digital object can be processed. Thus to improve the robustness and security of watermark, many scholars have made various research based on Fuzzy Logic Techniques.

NizarSakretal.[7] proposed a system based on Dynamic Fuzzy Inference System (DFIS) and Human Visual System (HVS). HVS parameters are calculated and applied to FIS, more than 20 rules are depicted to this FIS that are user defined. Fuzzy outputs are used to select the watermark embedding positions. In Reza Mortezaei et al.[8], developed a novel watermarking method built on fuzzy integral process to obtain the resemblance between DCT components of cover image and watermark signal, the components in together i.e.; cover image and watermark signal are arranged in zig-zag edict to find embedding position. Vaishali S. Jabadeetal.[9] developed a logo based watermarking method based on Discrete Wavelet Transform (DWT), Fuzzy Inference System (FIS) and Human Visual System (HVS). This scheme uses fuzzy inference system to insert logo/watermark. The weight of the watermark is determined by HVS characteristics and FIS. The image is reconstructed by computing inverse DWT to get watermarked image. The watermark is then extracted at the receiver end by applying DWT to watermarked image. Jun Fan et al.[10] projected a method grounded on kernel fuzzy clustering and singular value decomposition (SVD) utilizing wavelet transform for watermarking, the low-frequency singular value quantities after image complex wavelet is nominated as an inserted piece, styles the watermarked image. Mukesh C. Motwani et al.[11] proposed a method of fabricating a non-linear perceptual mask utilizing HVS model in wavelet domain and by utilizing fuzzy logic with input variables as brightness sensitivity, edge sensitivity, and texture sensitivity which are calculated for each transform coefficient. The result of the fuzzy inference system is an only entity giving perceptual significance for each equivalent wavelet coefficient, by which watermark is embedded. Sameh Oueslati et al.[12] proposed watermarking system accomplished in the wavelet domain which feats Human Visual System (HVS) and a Fuzzy Inference System (FIS) for medical images, watermark signal is embedded in the middle-frequency region, to achieve perceptual invisibility as well as robustness to attacks.

In the paper, a novel and blind watermarking technique utilizing discrete cosine transform and fuzzy inference system for embedding and extracting the watermark is presented. In this scheme, three fuzzy inference systems are used for embedding the watermark and at extraction it uses two fuzzy inference systems and the results are compared with SameshOuslatietal.[12] method.

The remaining paper is structured as: In section 2 Preliminaries about Discrete Cosine Transform, Human Visual System, and Fuzzy Logic are defined. Section 3 elucidates the projected watermarking system. Experimental outcomes are noted in section 4. Conclusions are specified in section 5.

2. Preliminaries

2.1. Discrete Cosine Transform

The DCT transforms a signal from a time domain representation to frequency domain representation. Embedding watermark into lower frequency components will cause imperceptibility problems, embedding into higher frequency components will not sustain to attacks such as compression etc., so to make algorithm more robust to known and unknown image processing attacks in this paper middle frequency components are considered.

Two dimensional DCT used in digital image processing for a given image A of size N*N is given as

$$\text{Cpq}= \alpha p \alpha q \sum_{m=0}^{M-1}\sum_{n=0}^{N-1} Zmn\left(\frac{\cos(2\pi m+1)p}{2M}\right)\left(\frac{\cos(2\pi n+1)q}{2N}\right), \text{ For, } 0\le p\le M-1,\ 0\le q\le N-1 \quad (1)$$

$$\alpha p = \begin{cases} \frac{1}{\sqrt{M}} & , \quad p = 0 \\ \frac{2}{\sqrt{M}} & , \quad 1 \le p \le M-1 \end{cases} \tag{2}$$

$$\alpha q = \begin{cases} \frac{1}{\sqrt{N}} & , \quad q = 0 \\ \frac{2}{\sqrt{N}} & , \quad 1 \le q \le N-1 \end{cases} \tag{3}$$

p and q varies from 0 to M-1, 0 to N-1 correspondingly, where M*N is size of original image. The DCT is reversible transform and its inverse is given by

$$\text{Zmn}= \quad \alpha p \alpha q \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} \text{Cpq} \left(\frac{\cos(2\pi m+1)p}{2M}\right)\left(\frac{\cos(2\pi n+1)q}{2N}\right) \tag{4}$$

2.2. Human Visual System

The human eye is subtle to different spatial frequencies, so the effect of noise in some areas of the image cannot be noticed by the human eye because of the same reason, in the human visual system model these areas are identified and the watermark is placed in these areas. The sensitivity of human eye to many frequencies is given by the frequency sensitivity. The effect of the imperceptibility of noise on a constant background is calculated by luminance sensitivity, texture sensitivity. This HVS model is also used in many insertion and detection algorithms of the watermark.

a) Luminance sensitivity (L_k):

Brightness is proved to be effective towards masking detectable noise on a continual background. The brighter the background is, the higher the size of noise can be i.e. embedded signal. The luminance sensitivity can be calculated by using the formula:

$$L_k = Y_{DC,k} / \overline{Y_{DC}} \tag{5}$$

Where $Y_{DC,k}$, is the DC quantity of the DCT of the k^{th} chunk, $\overline{Y_{DC}}$ is the average of all DC components of a definite image.

b) Frequency sensitivity (F_k):

If we split the image into 8x8 chunks and DCT is applied to each chunk, a 8x8 matrix will be formed of DCT components for each chunk. This matrix is separated into three parts, high-frequency (HF) components, low-frequency (LF) components, and medium-frequency (MF) components. In the 2D DCT matrix's upper left corner symbolizes low frequency component while the lowest right corner is the high frequency components. Image can be distorted if low frequency components are modified. Alternatively, since the compression process causes the DCT components to be detached in high frequencies, watermark cannot be embedded in high frequency components. So the central frequency components are utilized to embed the watermark.

c) Threshold Sensitivity (T_k):

The areas in an image can be divided into smooth, texture, and edge chunks. Texture areas are rough in nature and can withstand noise, i.e. noise cannot be noticed in these areas as it would also be mixed with the texture. The texture sensitivity is expected by rounding off the DCT components of cover image by means of the Joint Photographic Experts Group (JPEG) quantization table. The output is approximated to adjacent integers, and then the non-zero numbers are counted, this routine is calculated utilizing:

$$T_k = \sum_{x,y=1}^{N} \text{cond}\left(\frac{\text{Vk(x,y)}}{\text{Q(x,y)}}\right) \tag{6}$$

Where (x,y) is location in k^{th} block, cond(R) gives rounded value to 1 if value $\neq 0$, else 0 *d) Edge Sensitivity (E_k):*

The edge is identified within an image by utilizing verge procedure, the image processing toolbox in MATLAB software package outfits graythresh () function which calculates the chunk verge utilizing histogram-based. The application of this repetitive is as follows:

$$E_k = \text{graythresh (I)} \tag{7}$$

where I is the cover sub-image (chunk).

2.3. Fuzzy Logic:

Fuzzy Logic was presented by Lotfi A. Zadeh in 1965 as a means of expressing and controlling data that was not specific, but rather fuzzy. Fuzzy Logic begins with the idea of a Fuzzy set. There is a relatively strong connection between Fuzzy Logic and Fuzzy set theory.

2.4. Fuzzy Inference System

Fuzzy Inference is a procedure to map a particular input with a particular output utilizing Fuzzy Logic. This mapping offers a base from which judgments can be prepared. The procedure of Fuzzy Inference contains fuzzification, defuzzification, and knowledge base, shown in Fig.1, fuzzification converts the crisp value to linguistic terms, the Inference engine maps the linguistic terms based on the knowledge base and finally the defuzzification maps the linguistic terms to crisp values.

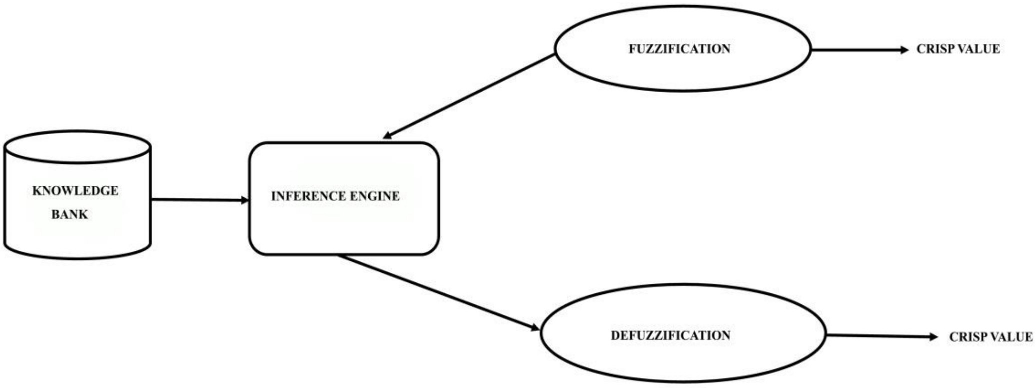

Fig. 1. Fuzzy Inference System

3. Proposed Method

3.1. Embedding Algorithm:

The procedure for embedding the watermark is:

1. Original Image is 512x512 pixels gray scale image and Original Watermark is 64x64 pixels binary image.
2. Divide the cover image (gray scale) into 8x8 blocks and apply DCT to each block.
3. Calculate Luminance Sensitivity (L_k), Texture Sensitivity (T_k), Edge sensitivity (E_k) and Frequency sensitivity (F_k) for each block.
4. Provide E_k and T_k as inputs to Fuzzy Inference System 1, L_k and F_k as inputs to Fuzzy Inference System 2.
5. The outputs of FIS 1 and FIS 2 are given as inputs to FIS 3, the output obtained is used as weighing factor.
6. Centre value in each block is taken as embedding location, and embedding is done utilizing the embedding formula,

if w=1
    X'= (s1(i)*s2(i))+s3(i);
else
    X'= (s1(i)*s2(i))-s3(i);
end
where X'=new DCT component,
s1,s2,s3 are FIS 1, FIS 2, FIS 3 outputs.

7. Take IDCT for every block and recombine the blocks to form the watermarked image.
8. Calculate PSNR for the watermarked and original image.

3.2. Embedding block diagram:

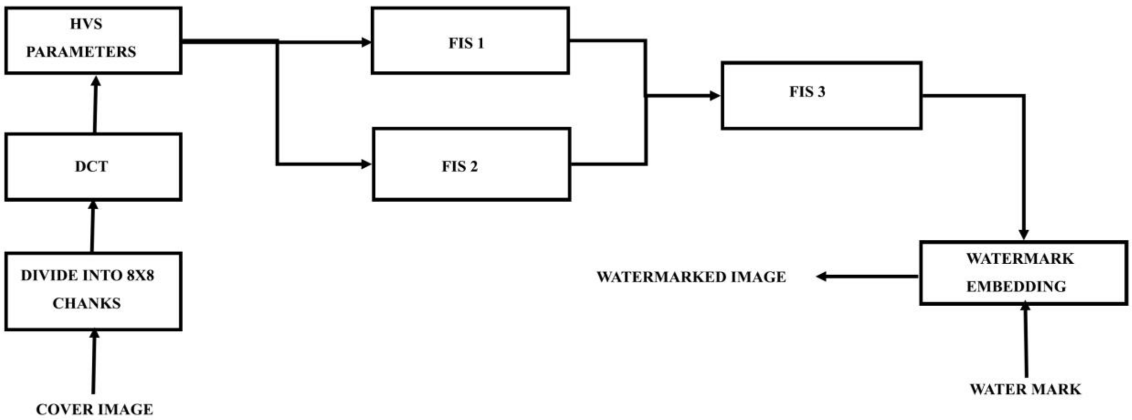

Fig. 2.Block diagram of embedding algorithm

3.3. Extraction block diagram

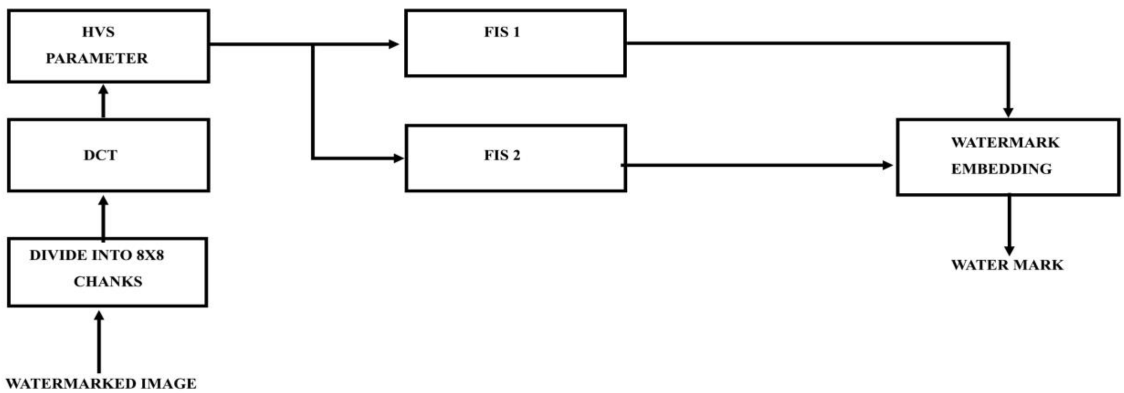

Fig. 3.Block diagram of extraction algorithm

3.4 Extraction Algorithm:

The watermark mining method is as per trails:

1. The Image is 512x512 gray scale image.
2. Divide the watermarked image (gray scale) into 8x8 blocks and apply DCT to each block.
3. Calculate Luminance Sensitivity (L_k), Texture Sensitivity (T_k), Edge sensitivity (E_k) and Frequency sensitivity (F_k) for each block.
4. Provide T_k and E_k as inputs to FIS 1, L_k and F_k as inputs to FIS 2.
5. Centre value in each block is taken and extraction is done utilizing the inverse of embedding formula,

```
if X”- (s1(i)*s2(i))>0
        w=1
else
    w=0
end
```

   where X”= DCT component of watermarked image,
   s1,s2 are FIS 1, FIS 2 outputs.
6. Rearrange the watermark bits to form 64x64 watermark image.
7. Calculate NCC for the extracted and original watermark.

4. Experimental Results:

The proposed method is tested on usual monochrome test images Lena and Mandrill of size 512x512 pixels with a watermark image of size 64 x 64 pixels, a logo taking the alphabets ‘JNTUACEA’ as shown in Fig. 4. In Fig. 5, the bar plot for NCC values obtained from proposed method and Sameh Oueslati et al.[12] method for different image processing attacks are shown. In Table 1, the NCC values for different attacks applied on test image LENA are shown. Image processing attacks applied to the watermarked image include row-column blanking, in which random rows/columns in the image are made zero, in the present result rows 175, 58, 10, columns 20,412,118 are made zero. In the rotation attack, rotate the watermarked image by angle 10 degrees. All the edges in the image are enhanced in sharpening attack. In histogram equalization attack, the watermarked image is enhanced utilizing histogram equalization method and watermark is retrieved from that enhanced image. The Watermarked image is passed through a low pass filter, median filter for filtering attacks. In this attack, the image is smoothened, and from this watermark image is extracted. Finally, the proposed algorithm also is resistant to row-column copying, JPEG Compression, salt and pepper noise, poison noise, resizing, bit plane removal, blurring, cropping, Intensity transformation, Image contrast attacks.

Fig.4. Test images LENA and MANDRILL of size 512x512 pixels with Watermark of size 64x64 pixels

The metrics utilized to verify the suggested scheme are Peak Signal to Noise Ratio (PSNR) and Normalized Cross correlation (NCC). The cover image is a size of *MxM* denoted as g*(i,j)*and let the watermarked signal equivalent be *G(i,j),* then PSNR is known by

$$\text{PSNR} = 10log_{10}\left(\frac{\sum_{i=1}^{M}\sum_{j=1}^{M}(G(i,j))^2}{\sum_{i=1}^{M}\sum_{j=1}^{M}(g(i,j)-G(i,j))^2}\right) \tag{8}$$

The watermark signal is symbolized by $w_m(i,j)$ and let the extracted watermark signal be symbolized by $w'_m(i,j)$ then NCC is given as

$$\text{NCC}= \frac{\sum_{i=1}^{M}\sum_{j=1}^{M}(wm(i,j)-wmean)(w'm(i,j)-w\prime mean)}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{M}(wm(i,j)-wmean)^2\sum_{i=1}^{M}\sum_{j=1}^{M}(w'm(i,j)-w\prime mean)^2}} \tag{9}$$

In Eq.(9), w_{mean} and w'_{mean} specify the average of the unique watermark image and extracted watermark signal correspondingly.

Table 1. NCC values for different attacks applied on test image LENA.

Type of Attack	NCC Values for Lena (PSNR 42.32dB)
No Attack	1
Row-Column Blanking	0.9919
Row-Column Copying	0.9860
Rotation(10^0)	0.7549
JPEG Compression	0.8940
Salt & Pepper noise (1%)	0.6450
Low Pass Filtering	0.7483
Sharpening	1
Intensity Transformation	0.9960
Resizing	1
Poisons noise	0.7175
Bit Plane Removal	1
Image Contrast attack	0.9840
Blurring	0.9038
Median Filtering	0.7890
Cropping	0.6456

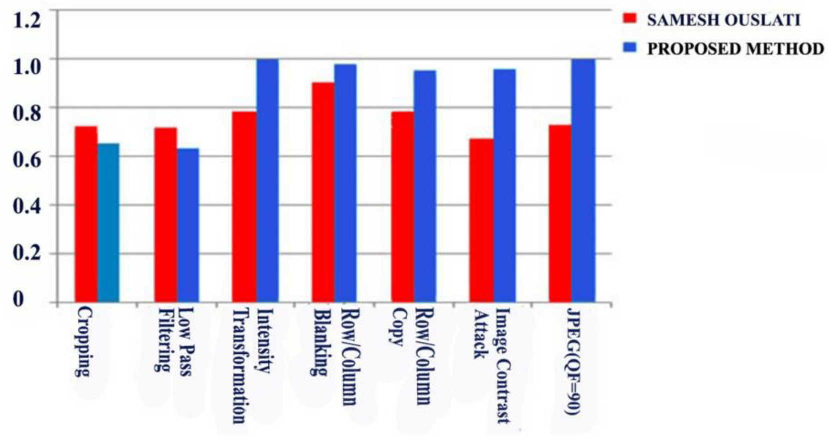

Fig. 5. Bar plot for the NCC values for proposed and Sameh Oueslati et al. method

5. Conclusions

In this research paper, an innovative and blind image watermarking algorithm grounded on Fuzzy Inference System (FIS) and Human Visual System (HVS) is proposed. The results are compared with the Sameh Oueslati etal.[12] method and the obtained outcomes indicates that the projected algorithm provides much more imperceptibility i.e. PSNR and robustness i.e. NCC to various image processing attacks such as Row-Column Copying, Row-Column Blanking, JPEG Compression Attack, Image Contrast, Image Transformation etc., and is also more secured.

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